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Water-related data are crucial for understanding the role of water ecosystems in sustaining both societal and economic functions, as well as for informing effective policy decisions. However, despite their critical importance, the accessibility and integration of such data often present considerable challenges. This paper examines the availability of biophysical data essential for the development of comprehensive Water-related Ecosystem Services (WES) accounts for the United Kingdom (UK), in alignment with the System of Environmental-Economic Accounting – Ecosystem Accounting (SEEA EA) framework. The study critically evaluates key data sources, identifies challenges associated with spatial and temporal coverage, and investigates potential solutions for addressing data gaps. By providing this analysis, the paper seeks to contribute to the advancement of a more standardized and systematic approach to water-related ecosystem accounting, thereby supporting more robust, evidence-based policymaking in water resource management.

Keywords: Water accounting; Biophysical data assessment; Water condition; Water-related ecosystem services; WES; Ecosystem accounting; SEEA-EA

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Introduction

Water is a vital resource for human survival, economic progress, and the health of ecosystems, shaping both environmental resilience and societal prosperity. Effective water management and policy development require access to a broad range of high-quality information; however, such data is often either lacking or poorly organized (Vardon et al., 2023). Several factors contribute to this issue, including the fragmented ownership of socio-economic and environmental water-related data across various agencies, inconsistencies in data approaches, spatial scales, and temporal coverage, and the limited efforts toward data collection and integration (Vardon et al., 2012). Water accounting presents a promising solution to these challenges, providing a structured method for synthesizing diverse data sources into a cohesive information system. By developing robust accounts, policymakers can better assess trade-offs, prioritize resource management strategies, and ensure the long-term resilience of water ecosystems in the face of increasing pressures such as climate change, population growth, and economic development (Vardon et al., 2023).

In this context, the UN System of Environmental-Economic Accounting (SEEA) framework offers international guidelines for harmonizing and standardizing environmental and economic data, integrating them with the System of National Accounts (SNA) to provide a more comprehensive view of natural resources within the broader economic system. Importantly, the SEEA accounts are designed to be consistent with the SNA, offering complementary insights into areas not fully covered by the SNA, while avoiding overlap or duplication. A key feature of both systems is their integration of stock and flow data, which allows for their mutual articulation. Tracking both stocks and flows is crucial for policy, as it provides a dual perspective on sustainability. On one hand, monitoring the value of produced and natural capital helps assess whether sufficient investment is being made to maintain these assets over time. On the other, analysing the associated flows reveals the benefits society receives from these assets and how effectively they are being used to support human well-being and economic activity.

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The SEEA framework consists of two principal components. The first is the SEEA Central Framework (SEEA CF) (United Nations et al., 2014), which provides the foundational international standard for environmental-economic accounting. It focuses on environmental assets, examining their use within the economy and their return to the environment. The SEEA Water (United Nations, 2012) further supports this framework by providing additional guidelines and methodologies for the accounting of water-related assets. The second component is the SEEA Ecosystem Accounting (SEEA EA) (United Nations et al., 2024), which complements the SEEA CF by evaluating the role of ecosystems in contributing to human well-being and the economy through the provision of ecosystem services (ES). Within this framework, ecosystem accounts integrate spatially explicit data and indicators to track the extent, the condition, the flows of ES, and the value of ecosystem assets over time at the national, regional, or local level.

While the SEEA framework provides a strong foundation, effectively addressing the environmental, social, and economic challenges of water resource management requires indicators that provide timely and reliable information. In this context. the UK provides a relevant example of both progress and ongoing challenges in achieving effective integration of water-related ecosystem services (WES) accounts and policy frameworks.

Natural Capital Accounting (NCA) in the UK is well-established and has been continuously refined over many years, with the Office for National Statistics (ONS) playing a leading role in its development. Building on this solid foundation, the ONS is currently updating its principles to better align SEEA guidance with the UK context (ONS, 2023). Despite the availability of extensive environmental data within the country, the creation of a fully integrated system of water accounts still faces challenges. This is largely due to fragmented biophysical data spread across multiple institutions, compounded by spatial and temporal inconsistencies that complicate the integration of ecological and economic datasets for developing comprehensive WES accounts. Addressing these issues is therefore critical for guiding future efforts to enhance data collection, standardization, and integration with international standards, supporting more informed decision-making in the UK.

The SEEA EA framework provides guidance to compile various accounts that capture different aspects of WES:

1. **Extent Account:** Quantifies the physical extent of water-related ecosystems over time and their net change between the opening and closing period.
2. **Condition Account:** Measures the quality of these assets across multiple dimensions and over time; may be supplemented by an Emission Account to track pollutants affecting water condition.
3. **Ecosystem Service Flow Accounts:** Capture the annual flow of the services provided by water-related assets and supplied to the economy and society in both physical and monetary terms, depicting their use across various sectors through a Physical Supply-Use Table (PSUT) and a Monetary Supply-Use Table (MSUT), respectively.
4. **Stock Account:** Determines the economic value of water-related assets by discounting the current and expected future supply of the ecosystem services from the asset to the economy and to society.

This paper explores the available data necessary for compiling the SEEA EA accounts, with a particular focus on the challenges associated with collecting comprehensive and reliable data for the UK. It also evaluates the spatial and temporal consistency of the existing data, highlighting the difficulties in ensuring the accuracy and completeness of the WES accounts. Furthermore, the paper proposes methodological improvements aimed at enhancing classification and ensuring better alignment with international standards, while leveraging available data. The focus is specifically on the physical data required for constructing the accounts in physical terms, given that considerations related to the monetary valuation of ecosystem service flow accounts and the stock account are discussed in Ferrini et al. (2025).

Extent account

Within the context of water ecosystems, the extent account aims to measure the surface coverage of freshwater bodies in terms of hectares and, where possible, the volume of water in lakes, reservoirs, and streams. However, two key considerations must be addressed. First, surface water represents only one aspect of the total water extent; other components such as groundwater, soil water, and wetlands should also be considered. While precise estimates may not always be available, approximate estimations based on existing research can still provide valuable insights for preliminary assessments. Second, understanding water inflows and outflows is crucial for evaluating the capacity of ecosystems to provide services across diverse geographical contexts. Therefore, the volume of water is particularly important, as it tends to fluctuate more readily than the surface extent measured in hectares.

In this section, we evaluate the data availability for the spatial distribution and extent of surface and groundwater resources in the UK, quantifying them in terms of area (e.g., hectares) and volume, while tracking the opening and closing stocks of these water ecosystems. The inclusion of groundwater is particularly important, owing to its unique interactions with other freshwater ecosystems, and is thus explicitly recommended by the SEEA EA framework.

Data availability to compile water extent accounts in the UK

The first requirement for generating effective accounts for policymaking is to rely on nationally standardized datasets, ensuring consistency across assessments while aligning with long-term monitoring efforts. In this regard, the most relevant spatial data sources for assessing the extent of the ecosystems in the UK are the UK Centre for Ecology & Hydrology (UKCEH) Land Cover Maps (LCMs). These maps provide a comprehensive, uninterrupted national dataset detailing land cover classification, including freshwater, grassland, woodland, and built environments. The UKCEH has a long-established history of using satellite imagery for land cover mapping, starting with the first national LCM of Great Britain in 1990 and continuing its publications up to the present for the UK[1]. Thus, these maps could act as a key reference for building both the SEEA EA accounts in physical terms, outlining the water-related ecosystems involved, and for determining the appropriate opening and closing periods for compiling them, ensuring consistency and coherence across the assessments SEEA is aiming to facilitate.

While the UKCEH maps provide a standardized land cover classification across the UK, using these maps to compile WES accounts presents several challenges, including the aggregation of the freshwater ecosystem categories into a single one, and difficulties in ensuring international comparability.

The first limitation arises from the land cover classification of the UKCEH maps, which is based on the UK Biodiversity Action Plan (BAP) Broad Habitats (Jackson, 2000). Specifically, this classification fails to distinguish between the various types of water bodies (e.g. rivers, lakes), a level of granularity that is recommended by the SEEA Ecosystem Type Reference Classification (United Nations et al., 2024). Instead, all the water bodies are grouped under the 'Freshwater' category. This implies that, although

[1] Raster maps are available for the years 2007, 2015, 2017, 2018, 2019, 2020, 2021, 2022 and 2023.

UKCEH LCMs are a rich data source of information, further pragmatic approaches to the disaggregation of the Freshwater category are needed for compiling SEEA accounts.

Recently, the ONS produced experimental estimates of ecosystem extent and condition for the years 1990, 2015, 2017, 2018, and 2019 (Office for National Statistics, 2022a). To achieve this, the ONS integrated summary area statistics derived from the UKCEH LCMs with the broad habitat categories established in the UK National Ecosystem Assessment (UK NEA, 2011). However, this additional integration process resulted in a loss of granularity, with various habitat types being aggregated into a single category encompassing freshwater, wetlands, and floodplains.

The second key challenge lies in ensuring global consistency and comparability across extent data mapping. For instance, the spatial data used at the European level are organised according to the CORINE Land Cover (CLC) maps, maintained by the European Environment Agency (EEA). While utilizing the CLC coverage would be ideal for ensuring consistency across nations, as demonstrated in previous studies (Farrell et al., 2021; Petersen et al., 2022), more accurate and granular data come from national environmental monitoring data based on the UKCEH LCMs classification.

Given these challenges, ensuring that the WES accounts are structured around the UKCEH LCMs remains the most relevant approach for producing consistent water accounts at the UK national level. However, it also is crucial to improve data granularity, particularly by distinguishing between diverse types of water bodies (e.g., rivers, lakes, groundwater bodies).

A potential refinement to enhance granularity could leverage on data collected under the Water Framework Directive (WFD) 2000/60/EC. Although the UK is no longer a member of the European Union and is not formally subject to EU directives, the WFD framework has been transposed into UK legislation and continues to underpin national water monitoring and classification practices, ensuring alignment with European reporting standards. Notably, the WFD classification provides a level of detail comparable to that recommended by the SEEA[2]. Table 1 shows a comparison between the SEEA Ecosystem Type Reference Classification (Keith et al., 2020a) and the Water Bodies Categories under the WFD (EEA, n.d.). This approach enables a detailed calculation of the extent of lakes, rivers, canals, transitional waters, and groundwater bodies in hectares, while ensuring a geographically consistent classification of freshwater ecosystems across the UK and the EU.

In terms of temporal coverage, as previously mentioned, extent accounts must include both an opening and closing period to track changes over time. In this context, the WFD data offer a valuable opportunity for long-term accounting, as the directive's monitoring of water bodies, began in 2009, follows pre-established six-year cycles. This approach could therefore ensure temporal consistency and facilitate the observation of trends and changes in water body extent over time.

Table 1. Comparison between selected SEEA Ecosystem Type Reference Classification (IUCN GET) for water-related ecosystems and WFD Water Bodies Categories (EEA).

SEEA Ecosystem Type Reference Classification		**WFD Water Bodies Categories (EEA)**
Realms	**Biomes**	**Category**
Freshwater	F1 Rivers and streams	Rivers

[2] The WFD data is organized according to a catchment hierarchy, starting from the largest to the smallest units: River Basin District, Management Catchment, Operational Catchment, and Water Body. The WFD defines water bodies as distinct units for monitoring, including rivers, lakes, canals, groundwater, and transitional and coastal waters.

	F2 Lakes	Lakes
	F3 Artificial fresh waters	Canals
Transitional	FM1 Semi-confined transitional waters	Transitional
	SF1 Subterranean freshwaters	Groundwater

Source: Keith et al. (2020a); European Environment Agency (n.d.)

However, the publicly available WFD data in the UK shows some limitations. The geographical boundaries of the WFD water bodies are published separately by the environmental agencies responsible for each region of the UK[3]. While for England and Wales the GIS data are provided for each cycle, for Scotland and Northern Ireland time series data about the water bodies' geometry are not publicly available. This limitation therefore hinders the possibility to track changes in the extent of water bodies in these countries between the reporting periods.

While recognising the temporal and spatial limitations of available data, we argue that combining the UKCEH LCMs and the WFD approach provides a means to enhance the assessment of water-related ecosystems, offering a more detailed and consistent framework for water extent accounting in the UK. To advance this proposal, several actions are required.

First, technical alignment between the spatial resolution and classification schemes used in the LCMs and those applied in WFD reporting is necessary. This could involve the development of a standardised crosswalk or mapping protocol, ideally coordinated through collaboration between the UK Centre for Ecology & Hydrology (UKCEH) and the national agencies responsible for collecting and publishing WFD data (as referenced in footnote 3). Such alignment would enable water bodies to be identified as a subcategory of the freshwater habitat classes defined in the LCM.

Second, governance arrangements should support the integration and regular publication of these datasets. This process would likely involve the Department for Environment, Food and Rural Affairs (DEFRA) and the ONS, as key actors in environmental accounting. Once established, this integrated approach could facilitate a more comprehensive and policy-relevant assessment of water extent accounts, providing a robust evidence base to inform both national and subnational policy priorities, including water resource management and climate adaptation strategies.

As previously mentioned, in addition to measuring the extent of freshwater ecosystems in hectares (or kilometres for rivers), the SEEA EA framework also emphasizes the importance of quantifying water resources in terms of volume. However, in the UK this type of information is spread among various agencies and is often misaligned, making it challenging to gather consistent data with spatial and temporal coherence. Ideally, it would be optimal to have time series data on the volume of water in lakes, the annual average discharge of rivers, and the annual average recharge of groundwater bodies for the same time span as the WFD cycles, ensuring consistency with the extent data in terms of area.

[3] In England, WFD data are managed by the Environment Agency (EA), in Wales by Natural Resources Wales (NRW), in Scotland by the Scottish Environment Protection Agency (SEPA), and in Northern Ireland by the Department of Agriculture, Environment and Rural Affairs (DAERA).

For lakes, the only dataset that provides volume information at the national scale is the UK Lakes Database (UKCEH, 2022). However, this dataset lacks a clear temporal reference, and the year of data collection is not specified. As a result, it is not possible to define an opening and closing period for the account, making it difficult to estimate changes in extent over time.

River flow records, including daily flow and peak flow estimates, are published by the National River Flow Archive (NRFA) and are accessible through the UK Water Resource Portal. Another significant dataset, which provides detailed information on both daily river flows and groundwater recharge, consists of hydrological projections for the UK based on the UK Climate Projections 2018 (UKCP18) data, as provided by the Enhanced Future Flows and Groundwater (eFLaG) project[4] (Hannaford et al., 2022). By employing advanced hydrological models (e.g. the Grid-to-Grid (G2G) model), this dataset offers [5]
and uses historical data from 1981 to inform projections to 2080, ensuring impressive temporal coverage. It follows that, for our accounting purposes, we are solely interested in the historical data up to the present, rather than the future projections.

Additionally, a critical source of comprehensive groundwater datasets in the UK is the British Geological Survey (BGS), which provides data collected on a daily or monthly basis through its inquiry service. However, a critical challenge arises in deriving average annual discharge of rivers and average annual recharge of groundwater bodies from daily data. To obtain accurate data for the entire accounting period and across all watercourses, considerable data aggregation efforts would be required.

After considering the various complexities involved, it becomes evident that while incorporating both the spatial extent and volumetric dimensions of water ecosystems would significantly enhance the extent accounts, the key challenge lies in ensuring the consistency, interoperability, and conceptual integration of complex and granular datasets. An effort is therefore required to leverage these valuable data for accounting purposes, ensuring consistency across both temporal and spatial dimensions. Ultimately, overcoming these challenges will be essential for developing robust and comprehensive water ecosystem accounts that align with the SEEA framework and support effective policymaking.

Condition accounts

While extent refers to the size of an ecosystem asset, the condition reflects its quality based on abiotic and biotic characteristics (United Nations et al., 2024). Building on the need to compile comprehensive WES accounts, aligning condition accounts with extent accounts is equally critical. According to the SEEA EA guidelines, condition accounts should capture multiple dimensions of ecosystem health, set out in the Ecosystem Condition Typology (ECT), which encompasses physical, chemical, compositional, structural, and functional states, as outlined in Table 2. However, a major challenge in compiling these accounts lies in identifying suitable variables and metrics for ECT. Some studies have focused on defining criteria and frameworks for indicator development (Czucz et al., 2021; Keith et al., 2020b; Vallecillo et

[4] eFlag uses three hydrological models (GR4J/GR6J, PDM and G2G), one groundwater level model (AquiMod) and one groundwater recharge model (ZOODR) to provide 'at site' simulations at the catchment or borehole scale.

[5] The datasets include river flow, groundwater level, and groundwater recharge time series for 200 catchments, 54 boreholes, and 558 groundwater bodies across Great Britain and Northern Ireland.

al., 2022), while others have explored semi-distributed hydrological and water quality models to integrate extent, condition, and ecosystem service accounts at the basin scale (Younesi et al., 2024).

Table 2. The SEEA Ecosystem Condition Typology (ECT)

ECT groups and classes	
Group A: Abiotic ecosystem characteristics	
Class A1. Physical state characteristics	Physical descriptors of the abiotic components of the ecosystem (e.g., water availability).
Class A2. Chemical state characteristics	Chemical composition of abiotic ecosystem compartments (e.g., water quality, water pollutant concentrations).
Group B: Biotic ecosystem characteristics	
Class B1. Compositional state characteristics	Composition/diversity of ecological communities at a given location and time (e.g., presence/abundance of aquatic species).
Class B2. Structural state characteristics	Aggregate properties of the whole ecosystem or its main biotic components (e.g., aquatic biomass, canopy coverage over water).
Class B3. Functional state characteristics	Summary statistics of the biological, chemical, and physical interactions within the ecosystem (e.g., primary productivity in aquatic systems, disturbance frequency in wetlands).
Group C: Landscape level characteristics	
Class C1. Landscape and seascape characteristics	Summary statistics of the biological, chemical, and physical interactions within the ecosystem (e.g., primary productivity in aquatic systems, disturbance frequency in wetlands).

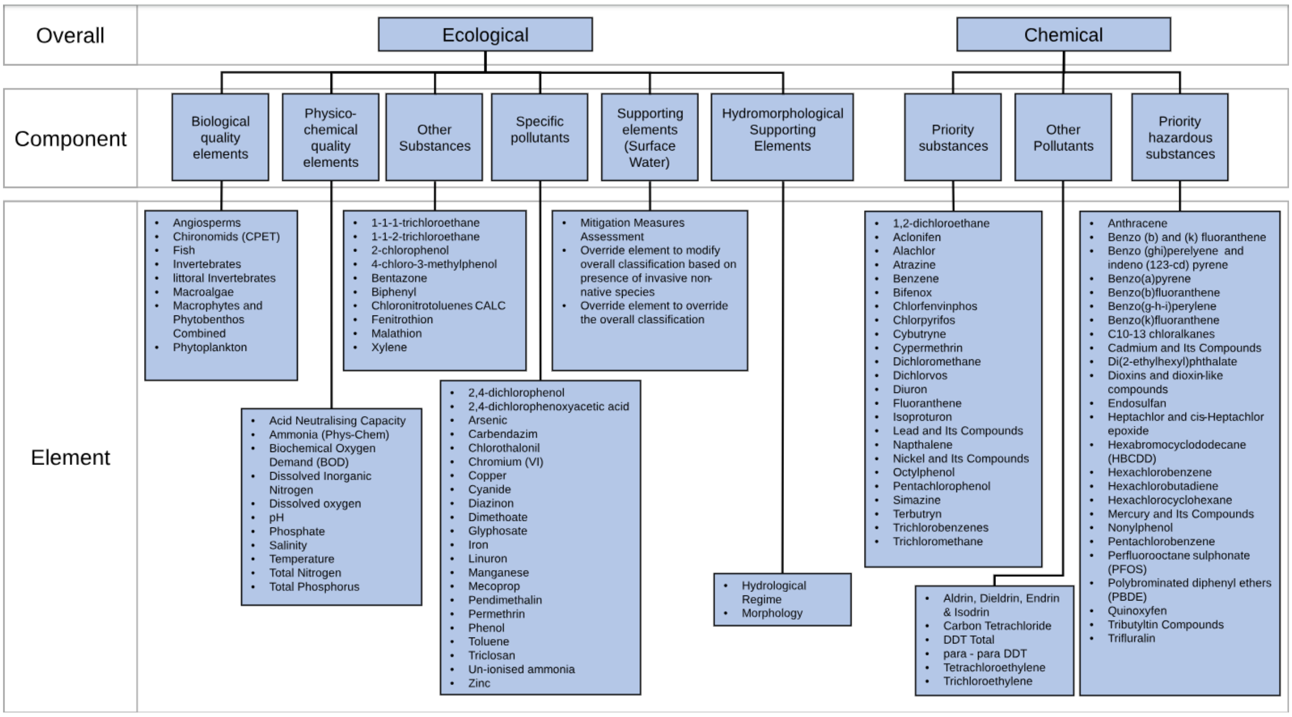
Source: United Nations et al. (2024)

In the UK, the ONS has released a set of experimental condition indicators, which encompass water-related metrics (Office for National Statistics, 2022b). However, these indicators do not fully align with the SEEA EA framework in several important respects. First, ONS indicators focus exclusively on the physical state (e.g., WFD classification for rivers and lakes, and soil pH and carbon concentration for wetlands and bogs) and the compositional state (e.g., species populations such as bats, birds, and salmonids), while data for the remaining three ECTs are missing. In particular, the chemical, functional, and landscape-level characteristics are neglected, despite being explicitly recommended by the SEEA for a comprehensive assessment. Furthermore, the indicators are reported without clear spatial attributes, which limits the ability to distinguish between the condition of different water ecosystems (or water bodies). These gaps undermine the completeness of the ONS set of indicators, necessitating additional information to enhance their potential for policy development and ecosystem management.

Despite these limitations, the extensive datasets available in the UK provide valuable insights into the characteristics of water ecosystems, offering a robust foundation to address key gaps in the ONS experimental indicators and enhance their alignment with the SEEA EA framework. The following section examines data sources that could potentially be used to meet the UN guidelines for condition accounts, with Table 3 providing a summary of their temporal coverage, key variables, and potential applications.

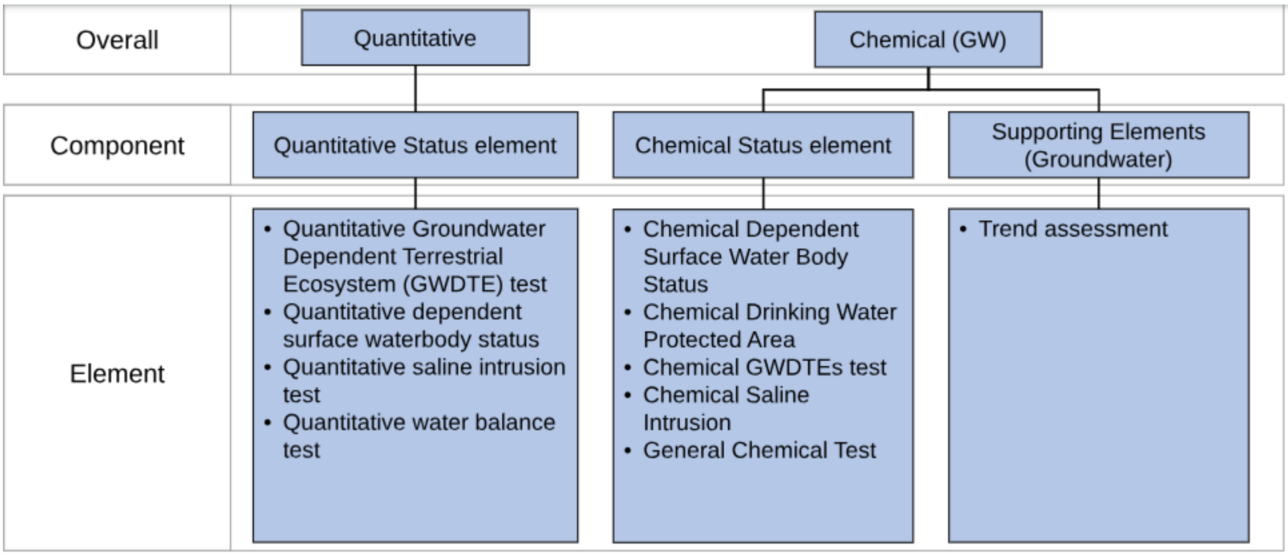
Data availability to compile water ecosystem condition accounts in the UK

According to the SEEA EA principles, the precise structure of ecosystem condition accounts depends on the ecosystem characteristics, data availability, intended uses, and policy applications. A potential source of condition data would be the policy-relevant classifications of surface water and groundwater established under the WFD. These classifications provide a standardized framework for assessing water condition, facilitate comparability across countries, and have been widely implemented in the literature to develop water-related condition accounts in various European countries, such as the Netherlands (Lof et al., 2019), Greece (Bekri et al., 2024), and Ireland (Farrell et al., 2021). Additionally, this approach could provide a high level of spatial detail and ensure consistency over time, as individual water bodies are systematically monitored across national territories on a recurring basis, as discussed earlier. Furthermore, if the WFD boundaries are employed to compile the extent account, as suggested previously, internal alignment within ecosystem accounts is maintained. Lastly, the hierarchical structure of the WFD classifications allows for a detailed assessment of water bodies' ecological, chemical, and quantitative status, considering various components such as biological and physic-chemical quality elements. The WFD classification hierarchy, along with the components considered, is illustrated in Fig. 1 for surface waters and in Fig. 2 for groundwaters. To align with the SEEA ECT, the chemical status indicators for surface and groundwaters could be used to assess their respective chemical state, while the ecological status indicator in Fig. 1 could be employed as the surface water compositional state, and the quantitative status indicator in Fig. 2 could be employed as the groundwater physical state characteristic.



Source: Environmental Agency (n.d.)

Figure 1. Classification hierarchy for surface waters.



Source: Environmental Agency (n.d.)

Figure 2. Classification hierarchy for groundwaters.

Although promising, the utilization of these data is subject to several limitations. Firstly, the WFD status classifications rely on a qualitative rating scale (i.e., high, good, moderate, poor, and bad) rather than a quantitative one. This may necessitate additional steps to achieve compatibility and measurable consistency among all condition indicators. Moreover, as previously mentioned, these data are published by the environmental agencies of each country, often leading to regional disparities in temporal data availability.

Given these considerations, the availability of additional data for each ECT group is examined below, with the aim of ensuring a comprehensive assessment of the relevant characteristics of water ecosystems while enhancing temporal coverage.

In relation to data that could potentially be used to evaluate the physical state of water ecosystems, a key source of hydrological indicators is the UK Water Resources Portal (UKCEH, n.d.). This portal provides key metrics such as the Standardised Precipitation Index (SPI), Standardised Streamflow Index (SSI), and Standardised Groundwater Index (SGI), offering long-term records of rainfall deficits or excesses, river flow variability, and groundwater level fluctuations. These indicators, derived from statistical models applied over standardized periods, serve as crucial measures of climatic variability and hydrological stress. A major strength of these indices is their standardized and uniform application across the entire UK. However, a key limitation is the unclear temporal coverage of observed data, as records vary by monitoring site and start date. Moreover, while historical time series can be downloaded for individual sites, developing a national-scale indicator would require additional processing to align time series, standardize methodologies, and aggregate data for consistency across regions.

As physical state condition indicators, it would be desirable to also include measures that capture human pressures on ecosystems. For instance, Water Bodies Achieving Sustainable Abstraction Criteria (B5) indicator from the Outcome Framework Indicator (OIF) from the 25 Year Environment Plan (DEFRA, n.d.)[6]. The spatial coverage includes rivers, lakes, reservoirs, estuaries, and wetlands dependent on groundwater across England. Similar data covering the entire UK would be highly beneficial to assess the sustainability of water abstraction across the broader context of the UK water bodies.

For the chemical state characteristics of water, more detailed and quantitatively scaled data are provided by the EA Water Quality Data Archive (Environment Agency, n.d.), which spans from 2000 to 2024. This dataset contains extensive measurements of water quality parameters, including nutrient concentrations, metal pollutants, and organic contaminants. However, its coverage is limited to England, leaving gaps in data availability for the rest of the UK. Furthermore, while the archive includes a wide network of sampling points[7], the data collected across these sites may not be uniform, as not all sampling locations measure the same set of parameters (determinants). This variability means that to ensure comparability between different sites, significant effort is required to standardise and harmonise the data.

Pollution and emission data are equally crucial for assessing the chemical state of water ecosystems. One notable indicator is the OIF Pollution Loads Entering Waters (B1), which tracks pollutants such as nitrogen, phosphorus, heavy metals, and biochemical oxygen demand in English rivers and tidal waters. This indicator consists of three components: riverine inputs of selected metals into English tidal waters, riverine inputs of selected nutrients into English tidal waters (both available from 2008 to 2019), and loads discharged to rivers from water company sewage treatment works in England, covering the period from 1995 to 2020. To construct this country-level indicator, data on riverine inputs of metals and nutrients are sourced from the OSPAR database, with the EA periodically reporting a subset of this data to DEFRA via the Riverine and Industrial Discharges (RIDS) dataset. For the sewage treatment works component, data are derived from measurements of effluent flow and concentration, or modelled values for smaller facilities. However, this indicator has several limitations. These include temporal

[6] The data includes the years 2017, 2018, 2019, and 2022, while data for 2020 and 2012 are missing.
[7] It contains 58 million measurements on nearly 4 million samples from 58 thousand sampling points.

inconsistencies in the data, the absence of more recent updates for certain components, and its geographical coverage being limited solely to rivers in England.

Another potential source for assessing the chemical ECT related to pollution is the Event Duration Monitoring (EDM) data on storm overflows, which provides annual records on the frequency and duration of sewage discharge events. In England, DEFRA publishes the data collected by Water and Sewerage Companies (WaSCs) as part of their regulatory Annual Return for the EA, reporting records from England's drainage systems, specifically concerning storm overflows, for the period from 2016 to 2023. Data for Wales can be found on the storm overflow maps available on the Dŵr Cymru Welsh Water and Hafren Dyfrdwy websites, while data for Scotland is available on the storm overflow map on the Scottish Water website.

The OIF Serious Pollution Incidents to Water (B2) indicator further documents high-impact pollution events that cause severe ecological damage, offering crucial insights into acute stressors affecting aquatic ecosystems. This indicator provides the number of serious pollution incidents in England from 2001 to 2022, without specifying which water companies recorded the incidents, making it challenging to trace the data back to specific regions. However, the number of Category 1 and Category 2 incidents from 2011 to 2019 for England, Scotland, and Wales was collected in a single dataset by the ONS (ONS, 2022a), although these indicators were not included in the condition indicators published in alignment with the SEEA framework (ONS, 2022b). Building on this effort, it would be ideal to create a composite indicator derived from data published by the environmental agencies of these countries, ensuring more recent data, consistent temporal coverage, and spatial units that are compatible.

To assess the compositional state of water bodies, the OIF's Health of Freshwaters (B7) indicator may be employed. This indicator evaluates fish populations in rivers, categorizing salmon stock resilience and the overall fish community status based on ecological classification systems[8]. It offers valuable insights into ecosystem functionality and the resilience of aquatic food webs. However, it is currently available only for England and provides national-level indices, without site-specific data.

To build an indicator for the structural state of river ecosystems, the River Habitat Survey (RHS) dataset, maintained by the EA, could be considered. This dataset allows for the assessment of habitat quality and the extent of channel modification. It provides indices, such as the Habitat Quality Assessment (HQA) and the Habitat Modification Score (HMS), which serve as the foundation for setting physical quality objectives for rivers. These indicators collectively provide insights into habitat suitability and the degree of human intervention in river ecosystems. Moreover, given that RHS captures broader spatial patterns of habitat structure and modification, these data could also align with the definition of landscape-level characteristics, thereby covering an additional dimension of ecosystem condition. However, the data are available for approximately 19,000 survey points of river ecosystems in England, while data for Wales are held by NRW and can be accessed through a data enquiry. To the best of our knowledge, no data have been collected for Scotland and Northern Ireland.

Potential data for assessing the functional state of freshwater ecosystems could be drawn from a key dataset developed by UKCEH as part of the ChemPop project (Bachiller-Jareno et al., 2024). This dataset

[8] The indicator consists of two components, one assessing the salmon stock status in principal salmon rivers in England from 2006 to 2022, categorizing rivers based on stock resilience into four risk categories, the other classifying the ecological status of fish communities in English rivers from 2009 to 2022, using five ecological classes. The data are sourced respectively from the EA Salmonid and Freshwater Fisheries Statistics and the EA WFD Cycle 2 River Fish Classification.

integrates biological, chemical, and physical parameters across 1,519 monitoring sites in English rivers, covering the period from 1965 to 2018. Among its various components, some of which have been previously mentioned[9], it includes macroinvertebrate taxonomic abundance, a crucial indicator of ecosystem function and aquatic food web dynamics, alongside site-specific physical characteristics. By consolidating these diverse data streams, the dataset facilitates a comprehensive assessment of how biological communities respond to environmental conditions, offering valuable insights into freshwater ecosystem functionality.

Finally, data on landscape-level characteristics offer valuable insights into the broader spatial dynamics influencing freshwater ecosystems and their overall health. For instance, the classification of Sites of Special Scientific Interest (SSSIs) identifies areas of high conservation value due to the presence of rare species, unique habitats, or significant geological features, serving as a key measure of ecosystem integrity. Their designation reflects the broader ecological quality of freshwater environments, making them a valuable indicator for assessing landscape-level characteristics within condition accounts. The temporal coverage of this classification is robust, as it was established under the Wildlife and Countryside Act 1981 and has been maintained continuously to the present. Additionally, spatial coverage is comprehensive, with GIS data for Great Britain provided by the countries' environmental agencies. In Northern Ireland, a similar classification exists in the form of Areas of Special Scientific Interest (ASSIs), which are designated and managed by the Northern Ireland Environment Agency (NIEA).

Table 3. Available datasets in the UK and suggested allocation to ECT classes.

Potential ECT Class	Dataset	Source	Temporal coverage	Spatial coverage	Data description	Limitations / Notes
A1. Physical state characteristics	Standardised Precipitation Index (SPI)	UK Water Resource Portal	Start of the record for each individual site - present	UK	Measures deficits or surpluses in precipitation over time, providing indirect insight into the physical availability of water (especially soil water).	Temporal coverage varies by site; national aggregation requires harmonization.
	Standardised Streamflow Index (SSI)	UK Water Resource Portal	Start of the record for each individual site - present	UK	Derived from average monthly river flows, it indicates the level of water in river systems and catchments.	As above.
	Standardised Groundwater Index (SGI)	UK Water Resource Portal	Start of the record for each individual site - present	UK	Evaluates groundwater levels, reflecting changes in hydrological conditions.	As above.
	Water bodies achieving sustainable	Outcome Indicator Framework	2017, 2018, 2019, 2022	England	Directly indicates the physical state of water resources in terms of their	England only; lacks UK-wide coverage and spatially explicit

[9] This dataset includes measurements of 41 water quality determinants derived from the EA Water Quality Archive, river flow data from NRFA, river habitat quality from RHS, and land cover from UK CEH LCM.

	abstraction criteria (B5)				sustainable management and potential pressures.	detail, data aggregated at national level.
	WFD Groundwater quantitative status	EA, NRW, SEPA, DAERA	2009-15 (Cycle 1), 2015-21(Cycle 2), 2021-24 (Interim Cycle 3)	UK	Based on the changes in groundwater level. If the amount of groundwater extracted exceeds the rate of recharge, the groundwater body will not achieve good quantitative status.	Qualitative scale; data updates not harmonised across UK countries.
A2. Chemical state characteristics	WFD Groundwater chemical status	EA, NRW, SEPA, DAERA	2009-15 (Cycle 1), 2015-21(Cycle 2), 2021-24 (Interim Cycle 3)	UK	Based on threshold values set for nitrates and pesticides, which could impact the quality of surface waters. If concentrations exceed these thresholds in a groundwater body, the water body fails to meet good chemical status.	As above.
	WFD Surface water chemical status	EA, NRW, SEPA, DAERA	2009-15 (Cycle 1), 2015-21(Cycle 2), 2021-24 (Interim Cycle 3)	UK	EU-wide standards are set for a list of priority substances. If the concentrations of these substances exceed the established limits in a water body, it fails to meet good chemical status.	As above.
	EA Water Quality Archive	EA Water quality data archive	2000-2024 (1960-2000 data requestable)	England	Water quality determinants measure the concentration of various chemicals in aquatic environments, which are crucial for evaluating the chemical state and pollution levels in water bodies.	England only; variable parameters across sites; requires harmonization.
	Pollution loads entering waters (B1)	Outcome Indicator Framework	2008-2019 (B1a, B1b), 1995-2020 (B1c)	England	Data on metals and nutrients loads entering rivers provides a direct measure of the emissions impacting the chemical state of rivers.	England only; temporal inconsistencies; some components not updated.
	Event Duration Monitoring - Storm Overflows	DEFRA, Welsh Water, Scottish Water	2016-2023	GB	Tracks the frequency and duration of storm overflow events, which are important indicators of water quality and chemical composition during extreme weather events.	Data fragmented by region; differing accessibility across GB countries.
	Annual serious pollution incidents to water	EA, NRW, SEPA	2011- 2023	GB	Sewage discharges into rivers influence the chemical composition of the water, impacting the aquatic ecosystem's health and water quality.	Limited spatial specificity; some datasets only cover England.
B1. Compositional state characteristics	Health of freshwaters (B7)	Outcome Indicator Framework	2006-2022 (B7a), 2009-2022 (B7b)	England	This indicator, including salmon stock status and fish community classification, reflects the biological composition and diversity of aquatic communities.	England only; national-level summary data without site specificity.

	WFD Surface ecological status	EA, NRW, SEPA, DAERA	2009-15 (Cycle 1), 2015-21(Cycle 2), 2021-24 (Interim Cycle 3)	UK	Expression of the quality of the structure and functioning of the water body. It shows the combined impact of pressures such as pollution, habitat degradation and climate change.	Qualitative scale; data updates not harmonised across UK countries.
B2. Structural state characteristics	River Habitat Survey (RHS)	EA, NRW	1994 - present	England, Wales	Assesses habitat quality and channel modification through indices like Habitat Quality Assessment (HQA) and Habitat Modification Score (HMS), providing insights into natural features and human interventions in river ecosystem.	England and Wales only.
B3. Functional state characteristics	Macroinvertebrate taxonomic abundance dataset (Bachiller-Jareno et al., 2024)	UKCEH	1965 - 2018	England	Summary statistics of the biological, chemical, and physical interactions within the ecosystem (e.g., primary productivity in aquatic systems, disturbance frequency in wetlands).	England only; historical coverage ends in 2018; incorporation of more recent data needed.
C1. Landscape and seascape characteristics	River Habitat Survey (RHS)	EA, NRW	1994 - present	England, Wales	Assesses habitat quality and channel modification through indices like Habitat Quality Assessment (HQA) and Habitat Modification Score (HMS), providing insights into natural features and human interventions in river ecosystem.	England and Wales only; irregular, periodic surveys.
	Sites of Specific Scientific Interest (SSSI)	Natural England, NRW, Scottish Government, NIEA	1981-present	UK	A formal conservation designation, which describes an area of particular interest to science due to the rare species of fauna or flora it contains, or important geological or physiological features in its boundaries.	UK-wide coverage; consistent spatial data available but held by different national agencies across the UK.

The broad availability of data across various environmental agencies highlights the opportunity to integrate these diverse datasets into a unified national water condition account, aligned with the SEEA framework. By consolidating this information, the UK can ensure a more systematic and data-driven approach to environmental accounting, enhancing the ability of these measures to effectively inform policymaking and support evidence-based decision-making for sustainable water resource management.

The ecosystem service flow accounts

Ecosystem services serve as the critical link between physical and monetary accounts. The first challenge in compiling these accounting tables is the selection of which water-related ecosystem services (WES) to include. While national policy priorities can play a role in shaping the emphasis or communication of certain services, the inclusion of WES in the accounts should be primarily guided by biophysical evidence and their broader value to society. The most frequently accounted-for WES include water provisioning, water purification, flood control, and water-related recreation (Vardon et al., 2025), although many other services exist (Chen and Vardon, 2024), and no fully exhaustive list has been established.

Equally important is the need to enhance the identification of the users of these services across various economic sectors and industries, as well as to accurately capture the supply of WES in physical terms. This ensures that all ecosystems contributing to each service are adequately represented.

Building on this foundation, the aim is to examine the available data for quantifying the supply of these services in physical terms and its use from different economic units, namely households, businesses, and governments. This paper aims to provide a discussion on the data available to provide one service from each of the three main ecosystem service categories, i.e. provisioning, regulating, and cultural. Specifically, the next sections will focus on water provisioning, water purification, and water-related recreation. These services were selected based on the relative availability and suitability of existing data to support physical accounting, as well as the need to develop a structured yet manageable approach by initially analysing one representative service per category. Other services, such as flood control, are also recognised as highly relevant and will be considered in future research, as their inclusion requires further investigation into existing data sources and the development of appropriate accounting approaches.

Water provisioning ecosystem service flow account

Within the SEEA EA framework, water provisioning refers to the physical flow of water from ecosystems to economic units as a final use or to other ecosystems as an intermediate use if ultimately extracted by an economic unit (Vardon, 2022). From a supply perspective, both surface and groundwater resources play a crucial role, alongside green water, which, despite its significant contribution to agriculture and other sectors, remains challenging to quantify and trace in terms of both supply and use. In the context of the use table, the primary objective is to ensure clear and accurate data on water consumption by economic sectors and households. Additionally, distinguishing between intermediate and final users is essential for a comprehensive understanding of water flows, although this classification falls beyond the scope of this paper.

Data availability to compile water provisioning PSUT for the UK

In the UK, the ONS has made a valuable first attempt to account for water provisioning within the UK NCA, compiling data on physical flows, annual values, and asset values from approximately 2002 to 2022 (Office for National Statistics, 2024). This effort represents a crucial step toward integrating ecosystem services into national accounting, highlighting the significance of water provisioning within economic and environmental assessments. However, certain methodological limitations prevent full alignment with the SEEA framework.

First, in terms of supply, the data report a single aggregated value for the habitat category 'Freshwater, Wetlands, and Floodplains,' a classification whose limitations have already been discussed in the section on extent accounts. Specifically, within the context of the water provisioning service account, this classification fails to distinguish between diverse sources of supply (e.g. surface water, groundwater), making it unclear which ecosystems or types of water resources contribute to the provisioning service. Similarly, no differentiation is made in relation to water use across economic sectors, preventing an accurate identification of the industries or consumers benefiting from these services. Furthermore, the reported physical flows appear to be derived from water abstraction statistics, but only for the 'Public

Water Supply' sector. Consequently, this approach does not adequately capture the actual end users who derive value from these ecosystem services.

To address this gap and achieve compliance with SEEA guidelines, a shift in focus toward identifying final users rather than intermediaries is essential. While improvements are needed, the ONS initiative provides a solid foundation upon which future refinements can build, particularly through a more detailed breakdown of water sources and user categories.

Several countries have developed water provisioning accounts in alignment with the principles of the SEEA, both at the national and local levels (Vardon et al., 2025). For instance, Edens and Graveland (2014) valued Dutch water resources, including soil water, in accordance with SNA and the UN guidelines. Similarly, Remme et al. (2015) developed accounts for groundwater provisioning for the Limburg Province (Netherlands), while Vardon et al. (2019) estimated water provisioning for the Central Highlands of Victoria (Australia). These examples offer valuable insights for refining the UK approach, particularly in relation to data selection for incorporating water provisioning services into national accounts.

The primary source of data for the water provisioning ES physical flow are water abstraction statistics. In the UK, these statistics are provided by each country by different regulators[10]. In England, these figures are published by DEFRA (DEFRA, 2022) and provide information on the number of licences held and estimates of average abstraction volumes (in millions of cubic meters), disaggregated by water source, including tidal surface waters, groundwater, and non-tidal surface waters, as well as by economic sector. While data on licences are available at the national level, abstraction volumes are reported separately for the seven regional charge areas defined by the EA. The sectors covered by these statistics range from public water supply, spray irrigation in both agricultural and non-agricultural contexts, and general agriculture, excluding spray irrigation, to electricity generation, industrial uses, fish farming, cress growing, amenity ponds, and private water supply.

A significant limitation of this dataset is its temporal coverage, as the most recent available statistics currently date back to 2018. However, updated figures covering data up to 2024 are not expected to be published until the second half of 2025, highlighting a substantial time lag in reporting. In the UK NCA, the ONS addresses this gap by drawing on supplementary sources. Specifically, for England, the ONS uses figures from the annual reports of the Drinking Water Inspectorate to estimate post-2018 trends.

Additionally, it is important to acknowledge the spatial inconsistency between these water abstraction statistics and WFD classifications' boundaries. The former is organized according to the seven EA Abstraction Regional Charge Areas in England, whereas the latter employs multiple spatial units of varying scales. Among these, the 10 River Basin Districts (RBDs) are the closest in size to the EA regional areas. Recognizing this mismatch is essential, as any attempt to develop regional accounts should ideally ensure consistency in spatial and temporal coverage. For instance, a policy-relevant aggregation approach, such as the NUTS1 level used in national statistics, could provide a more coherent framework for integrating these datasets.

For the other regions of the UK, acquiring data on water abstraction necessitates submitting a data inquiry to the relevant regulatory bodies, specifically Welsh Water, Scottish Water, and NI Water. For example, in its UK Natural Capital Accounts, the ONS makes use of data from the annual reports published by

[10] For England water abstraction statistics are provided by DEFRA, for Wales they are collected by Welsh Water, for Scotland by Scottish Water and for Northern Ireland by Northern Ireland Water.

Northern Ireland Water; however, these figures are limited to abstractions related to the public water supply sector. The lack of public availability presents a significant challenge in assessing the compatibility of their temporal coverage with that of England.

While data on abstraction primarily focus on groundwater and surface water, it is crucial to acknowledge the role of soil water (or "green water" in hydrological literature) in supporting agricultural activities. Soil water abstraction is defined by the SEEA CF as the uptake of water by plants, which corresponds to the amount of water transpired by plants plus the amount of water embodied in the harvested product (United Nations et al., 2014). Estimating this value is challenging, as there is no readily available annual data, and it typically requires calculation based on evapotranspiration, precipitation data, soil moisture, and other relevant variables. For instance, Edens and Graveland (2014) estimate soil water use by the agricultural sector by analysing evapotranspiration on agricultural land, focusing on crops' reliance on soil moisture in both unsaturated and saturated soil zones. In doing so, they employ data from a Eurostat-commissioned report on the water balance, which includes precipitation and evapotranspiration data for various land-use categories[11].

In the UK, precipitation data are provided by the Met Office (Met Office, n.d.), which offers rainfall time series at monthly, seasonal, and annual scales at both national and regional levels. Additionally, a key data source is the COSMOS-UK observation network, managed by the UKCEH (Cooper et al., 2021). This network, consisting of 47 soil moisture monitoring sites across the UK, has been collecting field-scale soil moisture and hydrometeorological measurements since 2013. It provides both directly monitored variables, such as precipitation (mm), soil volumetric water content, and temperature (% and °C), as well as derived variables, including the soil moisture index (SMI).

While recognizing the importance of soil water for the agricultural and forestry sectors, the allocation of this water resource within the SEEA CF or the SEEA EA accounts remains a critical issue, as highlighted by Vardon (2022).

Another crucial type of information to compile an accurate PSUT for water provisioning comes from the water companies. In England, a relevant source is the Annual Review Data from the Water Resource Management Plan, published by the EA. This dataset is updated annually and includes historical data from 2006 to 2023 for the 17 water companies serving England and parts of Wales. It covers several key metrics, including supply components such as raw and potable water abstraction, imports and exports, as well as demand components like consumption and leakage. Additionally, it provides data on properties, population, and the supply-demand balance, all measured in million litres per day (Ml/d). These variables are essential for understanding the dynamics of water resources, as they offer valuable insights into both water availability and demand, supporting effective management and forecasting.

An additional source of data from the water sector is the Water Companies Performance Data, covering the period from 2017 to 2024 (Ofwat, n.d.)[12]. This data is annually collected by Ofwat across the 16 largest water and wastewater companies in England and Wales, in order to assess their performance in

[11] The data is spatially and temporally explicit, derived from remote sensing technologies and precipitation radar data obtained from WaterWatch (E-Leaf).

[12] Historical data are available covering company performance up to the 2014-15 period, when Ofwat adopted a new company monitoring framework and performance reporting process. From 2011-12 to 2014-15, companies were expected to publish key performance indicators annually in four areas: customers, environmental impact, reliability and availability, and financial performance.

fulfilling regulatory obligations and meeting the commitments established in the Price Review 19 (PR19) determinations. This dataset includes information encompassing both environmental indicators, such as greenhouse gas (GHG) emissions (in tCO_2e) from water and wastewater networks and pollution incidents, as well as financial variables, including Outcome Delivery Incentive (ODI) payments (£m), Return on Regulated Equity([13],□, wholesale water expenditure, and wholesale wastewater expenditure. The economic data, however, are beyond the scope of this paper. For Scotland and Northern Ireland, equivalent data must be requested directly from Scottish Water and Northern Ireland Water, respectively.

Water purification ecosystem service flow account

The water purification ES refers to the contributions made by ecosystems in restoring and preserving the chemical quality of surface and groundwater bodies. This is achieved through the degradation or removal of nutrients and other pollutants by ecosystem elements that alleviate the negative impacts of these pollutants on human use and health (United Nations et al., 2024). To spatially allocate data on pollution loads and to accurately represent physical flow dynamics, the application of hydrological models is therefore essential. A pivotal study by JRC et al. (2021) offers a significant example in this regard. To provide water purification flow accounts for Europe, the authors consider nitrogen retention as a proxy, employing the GREEN hydrological model (Grizzetti et al., 2021) to calculate nitrogen inputs, the actual and potential removal flows of the ecosystem service, and to assess its overuse.

Data availability to compile water purification PSUT for the UK

As previously mentioned in the section on data availability for assessing the functional state of freshwater ecosystems, the UKCEH developed a valuable dataset for evaluating chemical exposure in aquatic ecosystems as part of the ChemPop project. This open-access dataset, which incorporates both biological and hydrological parameters, is designed to support a wide range of environmental analyses and modelling applications. In addition to macroinvertebrate abundance, it combines river flow information with chemical data, such as the Effluent Dilution Factor (EDF) and the EA Water Quality Archive data, which are particularly relevant for assessing water purification processes and their impact on ecosystem health. The temporal coverage of this dataset spans from 1965 to 2018. However, it can be extended to the present day for most of its components, particularly the EA Water Quality Archive, which remains continuously updated. Through the UK-SCAPE hydrological sensor data integration tool[14], it is possible to match the monitoring station IDs used in ChemPop with current data, enabling consistent and extended temporal analyses.

A valuable approach for estimating the water purification service provided by river systems involves the use of ecological-hydrological models, as the ones developed by UKCEH. These models do not possess an intrinsic temporal coverage, as their outputs are determined by the spatial and temporal resolution of the input datasets used for each simulation. This characteristic represents a methodological advantage, enabling consistent, scalable, and repeatable assessments over time, provided that appropriate input data are available.

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[13] Specifically, the dataset reports: the total RoRE, showing total ODI payments against notional regulatory equity; the RoRE by Price Control, which presents ODI payments broken down by price control relative to notional regulatory equity; and the RoRE by Performance Commitment, which shows ODI payments disaggregated by performance commitment, also against notional regulatory equity.

[14] https://eip.ceh.ac.uk/hydrology-ukscape

Prominent examples include SAGIS[15], SEPARATE[16] and QUESTOR[17]. SAGIS was developed for the UK Water Industry Research (UKWIR), with support from regulatory agencies, and estimates chemical pollution at the river basin scale by integrating national datasets on point and diffuse pollution sources. SEPARATE, produced under the DEFRA project WQ0223, functions as a screening-level tool for estimating annual nutrient and sediment loads across English and Welsh rivers, disaggregated by source type at the WFD water body scale.

Among these, QUESTOR represents the most ecologically comprehensive modelling framework. It simulates river water quality and ecosystem health under varying climatic and management scenarios by producing high-resolution time series of key water quality parameters such as temperature, nutrient concentrations, algal biomass, and dissolved oxygen. These outputs serve as integrated indicators of ecological condition and are directly aligned with regulatory standards, offering a robust basis for quantifying water purification services and assessing ecosystem health.

However, the full potential of these modelling tools can only be realised through close collaboration between environmental economists and ecologists. Such interdisciplinary integration is essential to advance ecosystem service accounting that are not only biophysically accurate but also socio-economically meaningful, thereby supporting evidence-based environmental policy and sustainable water management.

Water-related recreation ecosystem service flow account

Regarding the water-related recreation ES, the biophysical flow is usually estimated using the number of visits to the ecosystem of interest (Lankia et al., 2020, Lankia 2023, Valecillo et al. 2019, Bartolini et al. 2024). Additionally, data on water quality related to the sites should be considered to assess the suitability and attractiveness of the ecosystem for recreational activities.

Data availability to compile water-related recreation PSUT for the UK

For England, the People and Nature Survey (PaNS) provides data on visits to rivers, lakes, and canals, offering insights into public engagement with the natural environment. Conducted by Natural England in partnership with DEFRA since 2020, PaNS consists of two annual, nationally representative surveys[18]. PaNS replaced the Monitor of Engagement with the Natural Environment (MENE) survey, which ran from 2009 to 2019[19]. The dataset contains approximately 1,000 annual observations on water recreation, with 700 focused on freshwater activities. It records respondents' locations, visit frequency, and recent recreation sites over a four-year period (2020–2024). This survey has also been conducted for Wales (PaNS Wales) and Scotland (SPANS). PaNS Wales commenced in 2021 and collects data from adults (16+) across Wales via an online panel (Natural Resources Wales & Natural England, 2024), while SPANS was first conducted in 2013/14, followed by a second iteration in 2017/18, and subsequently on a regular basis up to 2024 (Stewart & Eccleston, 2024). The data for England and Wales are publicly accessible, while the data for Scotland are published annually in reports. However, it is important to

[15] https://catalogue.ceh.ac.uk/documents/57c40da0-2dc7-43a1-8291-f9ae2fd0a18d
[16] https://catalogue.ceh.ac.uk/documents/427bf467-002a-477f-a227-8dd4950d0b47
[17] https://catalogue.ceh.ac.uk/documents/906ea32c-1005-45a2-afbe-86619e8bc45f
[18] One surveys approximately 25,000 adults (A-PaNS), while the other surveys 4,000 children (C-PaNS).
[19] Key differences include PaNS's online data collection, the inclusion of a children's survey, and an updated questionnaire and sampling framework. Due to these methodological changes, Natural England provides a guidance document with further details on comparability between PaNS and MENE.

emphasize that these datasets require data refinement to ensure their suitability for estimating the physical flow of the recreation WES, including the integration of water quality information.

Conclusions

This study has highlighted the extensive availability of hydrological data in the UK to support the compilation of WES accounts in alignment with the SEEA EA framework. However, this abundance of data sources is counterbalanced by significant challenges related to data dispersion, temporal and spatial inconsistencies, and fragmented ownership across multiple national agencies. These factors complicate the collection, integration, and harmonization of relevant datasets.

Addressing these challenges necessitates a structured and systematic approach. The first step involves the comprehensive identification and assessment of available data, alongside a critical evaluation of their usability constraints. Following this, the second step requires the development of methodological refinements and technical solutions aimed at improving data integration and coherence, many of which demand highly specialized expertise.

This paper has outlined several approaches to leveraging existing datasets, but a more comprehensive and long-term solution would involve the development of an integrated dataset or a tool capable of consolidating these disparate data sources into a coherent framework. Such an endeavour would require sustained effort, resources, and, crucially, interdisciplinary collaboration among hydrologists, ecologists, statisticians, and economists. Equally important is the establishment of appropriate institutional arrangements and enabling conditions to make such collaboration effective, including mechanisms for coordination, data governance, and sustained funding. Ideally, the various disparate sources of water data should be extended or adapted to feed into a broader, integrated system that supports long-term environmental-economic accounting.

Where persistent gaps remain, particularly in spatial resolution or update frequency, exploring the potential of geospatial technologies and Earth Observation (EO) data could provide valuable complementary insights. Although EO cannot replace administrative or in-situ records, its spatially explicit and regularly updated information may help fill data gaps or aid validation, making it a promising area for further research as related methodologies evolve.

Beyond improving current data integration, ensuring the continuity and consistency of data collection over time represents a third and essential step. Establishing robust and standardized data collection protocols would not only enhance spatial and informational coherence but also facilitate automation in the compilation of WES accounts. This aligns with international best practices in the compilation of water accounts, as seen in the Netherlands, which employs R-based approaches, and Germany, which utilizes SAS.

Moving in this direction would not only align the UK with international best practices and UN guidelines for environmental-economic accounting but also establish a robust strategy for the long-term compilation of high-quality, policy-relevant water accounts capable of supporting decision-making.

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